Stefano Redaelli, 28-06-2007

86th Meeting of the LHC Collimation Working Group, May 7th, 2007

Present: Ralph Assmann (chairman), Giulia Bellodi, Alessandro Bertarelli, Dariusz Bocian, Chiara Bracco, Markus Brugger, Francesco Cerutti, Alfredo Ferrari, Daniel Kramer, John Jowett, Luisella Lari, Jacques Lettry, Marco Mauri, Manfred Mayer, Valentina Previtali, Stefano Redaelli (scientific secretary), Stefan Roesler, Alexander Ryazanov, Mariusz Sapinski, Lucia Sarchiapone, George Smirnov, Joachim Vollaire, Vasilis Vlachoudis, Thomas Weiler.

1 FLUKA studies for LHC scrapers (F. Cerutti)

1.1 Simulation results

Francesco Cerutti presented recent studies performed for the LHC scraper design. The goal of these studies is to come up with a limited list of choices for basic scraper parameters, such as length and material, to start more detailed engineering studies.

The preliminary simulations performed by F. Cerutti and M. Brugger assumed that the scraper moves instantaneously from infinity to an amplitude of 3 sigmas from the beam core (basically, it intercepts in one turn the Gaussian tail of the beam distribution). This is not a realistic assumption because it implies infinite jaw speed, however it provided some preliminary case study for various materials. For Carbon, it was found that the ideal scraper thickness would be of the order of 20 cm.

The simulations were then improved by assuming an impact parameter of 100 nm. In this case the optimum (i.e. minimizing the energy deposition peak) scraper length for Carbon is still between 10 cm and 40 cm. Francesco warned that for such small impact parameters the alignment accuracy becomes an issue and therefore the results of these simulations must be given an adequate safety factor (reality might be very different, in particular for long scrapers).

Last step in simulations was to consider for the impact parameter a flat distribution 100 nm large along the scraping direction. In the dimension orthogonal to the scraped plane, a Gaussian distribution was considered. Francesco claimed that this is the most realistic simulation scenario that has been considered. Due to the very small beam size, simulations predict that a very high energy density will be deposited into the scraper. On the other hand, estimates by Alessandro Bertarelli show that the deposited heat diffuses away from the 100 nm impact area within a few nanoseconds, see slide 16. However, pile-up effects from bunch to bunch still play a major role. Alfredo Ferrari re-iterated that in these simulations we cannot neglect the heat diffusion from one bunch to the next one otherwise we get very high peak deposited energy values. A. Bertarelli commented that nevertheless after 25 ns the next bunch will see a temperature rise of about 80 degrees, which is quite significant even though well below the previous estimates.

In conclusion, Francesco Cerutti showed a summary table with the total deposited energy in scrapers of different lengths, made of Copper and Tungsten. For example, the deposited energy in a 1 mm long scraper is 2 MeV/p for Copper and 5 MeV/p for Tungsten. It is noted that these energies are calculated per crossing proton and not per absorbed proton. Francesco commented that the key point for the scraper design will be to reduce the pile-up effects from consecutive bunches. More detailed simulations should take as an input detailed proton distribution maps in the scrapers from tracking.

1.2 Discussion

R. Assmann asked about the study of the effect of the beam size on the energy deposition estimates (graph at page 13 of F. Cerutti's slides). Ralph pointed out that in the range of interesting lengths there is no convergence. A. Ferrari replied that by definition there are big differences because in simulations we use bin sizes above the scraper area where the beam is impinging. On the other hand, if we went below bin sizes of 100 nm the simulations would take too long.

S. Redaelli commented that the distribution assumed in simulations for the primary beam impacting on the scraper (100 nm $\times$ Gaussian along y) is actually an optimistic assumption. If the scraper gets closer and closer to the beam core along one plane, it will never see the full beam size on the orthogonal plane unless it jumps into the beam core at unrealistically high speed.

A. Bertarelli reiterated that you cannot take into account the instantaneous energy deposition, which is a good news because the estimated peak temperatures become lower. However he also pointed out that the temperature left after 25 ns will leave be still significant and the bunch-to-bunch pile-up will occur. R. Assmann commented that, if we really believe that these short time scales must be taken into account, then one should use the real LHC bunch filling scheme (which included gaps much longer than 25 ns).

Referring to some simulations performed by S. Redaelli (see slide 19 of Francesco's presentation), Jacques Lettry asked why the full jaw speed was considered. Can we reduce the speed (or equivalently the number of steps per second) in order to reduce the deposited energy in the scrapers? S. Redaelli replied that this simulation was a preliminary study done to estimate what is the maximum beam intensity that one can scraper by moving the scraper at the nominal speed. The optimum operational speed for full beam intensity should actually be an output of the energy deposition studies.

R. Assmann proposed that we should come up with a smaller set of case studies for scraper material and length and then perform more detailed tracking simulations for these cases. A. Bertarelli suggested that the best candidate should be a fairly short metal. A. Ferrari agreed and pointed out that, as far as the hadronic showers are considered, we will be dominated by ionization processes and hence it does not really matter to use metals. This choice is instead driven by the optimization of the heat-flow.

R. Assmann then proposed the following work plan (1) R. Assmann and S. Redaelli will provide further inputs to the FLUKA team (proton loss maps based on tracking studies); (2) the FLUKA team will perform detailed energy deposition studies; (3) A. Bertarelli will follow up the scraper design based on these inputs. The basic goal is to achieve a scraper design that can stand the full LHC beam. Everybody agreed with the proposed work plan however S. Redaelli was skeptical because he believes that there is no need to perform many detailed tracking simulations to provide relevant operational scenarios to be used for thr scraper design. For example, we know that by cutting the beam tails about 2.5 sigmas we intercept already an energy larger than design criterion of the collimation system. Studies should first be focused on determining the maximum intensity that we allow to cut with the scraper. R. Assmann replied that one could envisage sub-micrometric scraper speeds in order to cut slowly small slices of the beam, if required.

R. Assmann concluded the discussion by commenting that it looks very challenging to achieve a scraper design that can perform significantly better than the primary collimators. They can probably be used as scrapers in the early LHC runs. R. Assmann also suggested that in following simulations the Aluminum should also be considered as a possible candidate for scraper material.

Follow-up after the meeting: The scraper design studies can be delayed because the scrapers will not be produced within the Phase I collimation budget and hence will not be installed before the shutdown after the 2008 run. Design studies should nevertheless continue in order to make sure that we will be ready for this deadline.

2 Status and plan for LHC ion collimation (J. Jowett)

John Jowett discussed status and plans of the LHC ion collimation. John started with a summary table of the ion beam parameters and reviewed the outstanding issues of the ion collimation. Then John reviewed the latest loss map studies for ion and the proposed BLM layout in the cleaning insertions. These studies, performed by Giulia Bellodi and co-workers, have been extensively discussed in previous meeting of the LHC collimation working group. The LHC Project Note 399 that describes in detail these studies has recently been published. This note also described the final layout of the beam loss monitor installation downstream of the For future studies it is planned that FLUKA calls will be integrated into the ICOSIM code by H. Braun in order to replace the replace the old table of ion cross-sections. A parallelization of the tracking tools is also under investigation.

R. Assmann warned that putting too much effort in the integration of FLUKA within ICOSIM might not the a good investment of resources because ICOSIM does not provide very sophisticated tracking functionalities. Other urgent studies of the FLUKA should not be delayed. J. Jowett commented that G. Bellodi is also working on advancing the ICOSIM functionalities.

J. Jowett also commented that SPS MD's with beam are foreseen for this year to benchmark the ion tracking tools and to understand the signal response of the LHC-BLM's to ion beam losses. John stated that help is expected form the collimation and BLM teams, who will be welcome to join the MD's.

J. Jowett also reviewed some advanced collimation concepts that are being investigated. He mentioned the proposal of magnetized collimators. H. Braun's preliminary estimates suggest that an integrated field of only 0.2 Tm could be sufficient to increase significantly the impact parameter of primary ion beams on the primary collimators and hence the overall cleaning efficiency. Various ideas for the magnetized collimator geometry are under discussion. A student is foreseen to join the ion team to perform detailed electromagnetic calculations.

R. Assmann commented that a critical issue for magnetized collimators will be the effect on the beam core. He agree that a detailed magnetic model is needed.

J. Jowett enumerated other studies under investigation, such as the non-linear collimation, the hollow e-beam (which would avoid ions interacting with matter and would not affect the beam core) and the crystal collimation. On this last item, George Smirnov will report at one of the next collimation meeting. John also reminded that MD's with extracted beams in H8 are foreseen for this year in order to assess the crystal efficiency for ion beams.

In conclusion, John stated that the collimation of ion at the LHC can be a problem. We have operational scenarios to attenuate the problem however additional studies are ongoing to achieve the requirements of nominal ion beams

R. Assmann reminded an open issue from previous meeting and stressed that we should look into the use of TCLA's of IR3 and IR7 to improve the ion cleaning.

The next meeting will be announced.